Ocean E-Field Measurements Using Gliders

Thomas B. Sanford
Applied Physics Laboratory and School of Oceanography
University of Washington
1013 NE 40th Street
Seattle, Washington 98105
Phone: (206) 543-1365 fax: (206) 543-6785 email: sanford@apl.washington.edu

Award Number: N00014-07-G-0057

LONG-TERM GOALS

Our long-term technical goal is to determine the limits of applicability of ocean electric field for vessel detection, classification and location on mobile and stationary platforms.

OBJECTIVES

Our primary objectives are to improve the sensitivity, size, power and usefulness of ocean electric field sensor systems on ocean-going, autonomous, mobile platforms.

APPROACH

Our approach is to design, install and operate E-field sensor components on the UW Seaglider. This project involved the development of special preamps and operating them as a 3-axis, mobile E-field sensor system (Fig. 1).

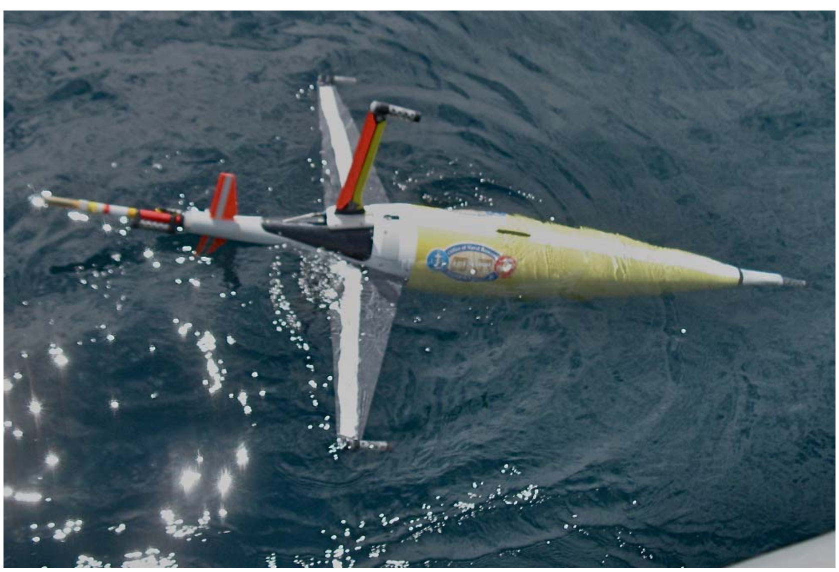

Fig. 1: 3-axis EF-Seaglider (EFSG) with electrodes on nose and tail (longitudinal axis), opposite wing tips (transverse axis) and top and bottom of vertical stabilizer (vertical axis). Because of instrument roll and pitch motions, the components are not horizontal and vertical. However, the observed pitch and roll values will be used to resolve observed components into the desired horizontal and vertical axes.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**
4. TITLE AND SUBTITLE **Ocean E-Field Measurements Using Gliders**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Washington,Applied Physics Laboratory and School of Oceanography,1013 NE 40th Street,Seattle,WA,98105**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

- Added Z (aka vertical) electrode on EFSG 125.
- Completed construction of 2-axis EFSG 123.
- Conducted sea trials in Puget Sound, WA, including a test of 3-axis EFSG in free flight.
- Prepared EFSG 123 and 125 for ASWEET10-1.
- Prepared towed EF source.
- Attended PLUS INP Team Leader meeting in Alexandria in May.
- Shipped instruments and support gear to SPAWAR San Diego.
- Conducted in-ocean studies of ocean E-field in ASWEET10-1 in September–October 2010.

RESULTS

EFSG 125, a 3-axis EF Seaglider, was flight tested in Puget Sound in preparation of shipment to ASWEET10-1 field operations. The effort identified the signals produced by various glider operations, such as the oil pump and roll/pitch motors. Figure 2 shows an example of observations from the towed EF source in Pre-ASWEET. The observed EF is a combination of the USNS *Sioux* and the DC signal from an EF source towed about 100-m behind. Figure 2 presents time series and hodographs of the three EF channels taken two at a time. The ship and the towed source of amplitude 450 A•m DC moved at a speed of 4 kt at an angle of about 30° with respect to the sensor axes. The CPA occurs at the maximum value of both axes. Ch. 1 is nearly that of the along asymmetric EF typical of the signal parallel to the orientation or track of the source. Ch. 2 is more nearly the parallel component. N.B., The vector components have not been corrected for roll and pitch. That is, they are not rotated into true horizontal and vertical components. The classic example uses the two horizontal axes. This is shown in the top right panel. The cardioid pattern is expected from a moving static dipole with a track offset from the sensor. The middle right panel provides information about the offset or horizontal separation between the source and sensor.

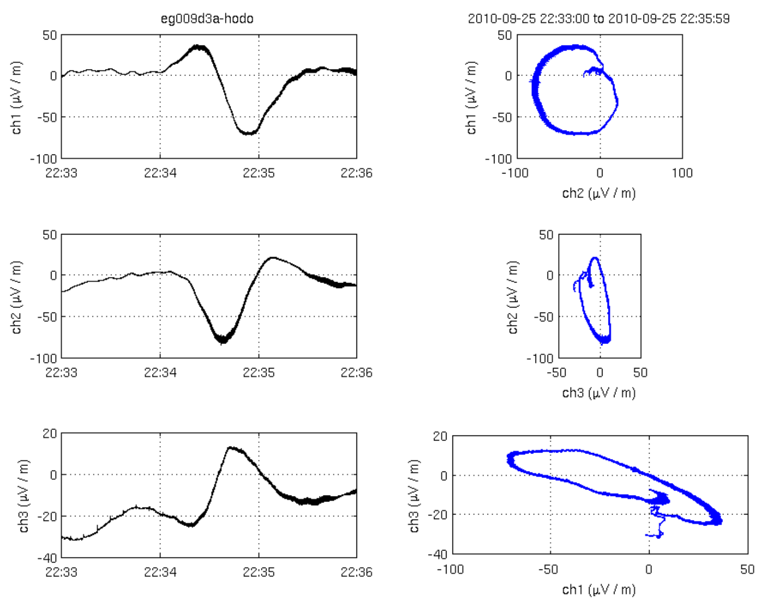

Fig. 2: Observed orthogonal E-field components. The observations are a bit complex because the signal consists of the static field of the USNS* Sioux *and the deliberate DC signal from the towed EF source. EFSG is at 40-m depth during the passage of the vessel and towed source.

In addition to installing custom E-field sensors on the Seaglider, we improved an electric current dipole source (Fig. 3). This was used to evaluate the performance of the EFSG in the ocean. The source can produce either DC or any chosen low-frequency AC electric current. The tantalum electrodes, each 1.22-m long, are spaced 15.3 m apart (center-to-center). Each electrode is suspended from a float and held at 2-m depth with a V-fin depressor and has a SBE-39 temperature and pressure recorder to monitor electrode depth.

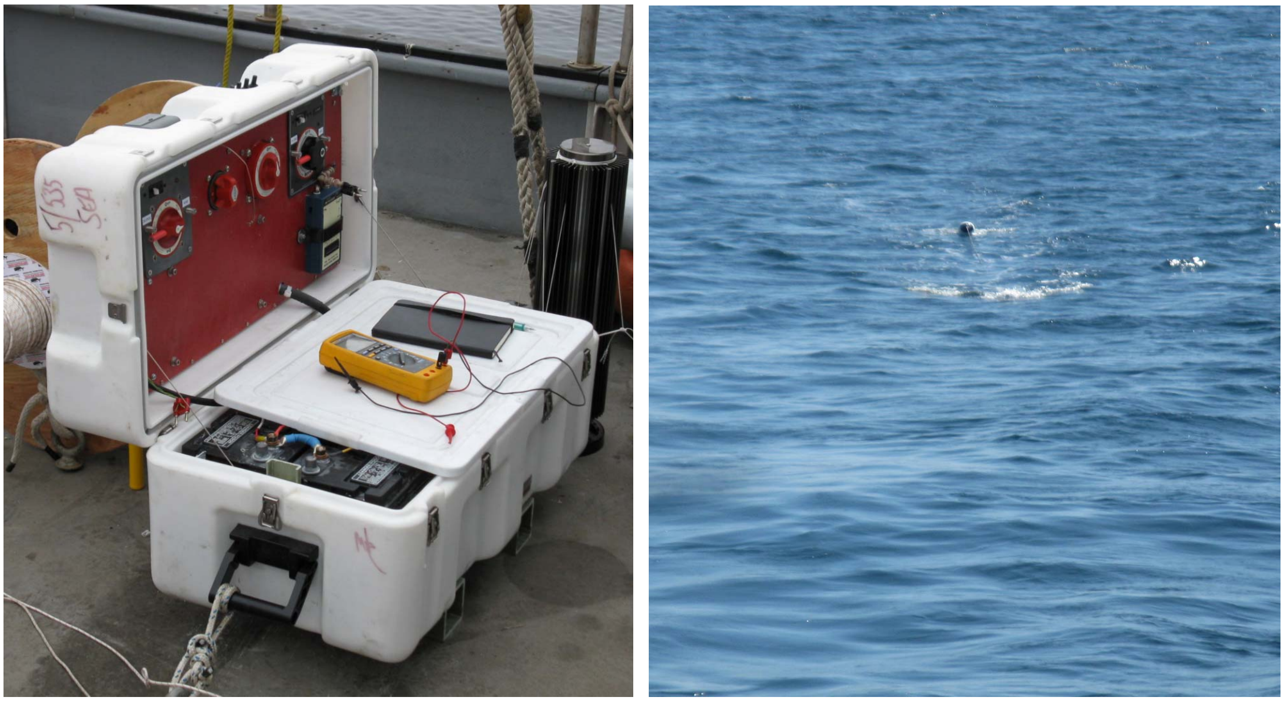

***Fig. 3: Electric current dipole source. Batteries provide 48 V for DC and selected AC currents. The source electrodes are towed about 100 m behind the* vessel *and are separated by 15.3 m. The tow speed was usually 4 kt*.**

Figure 4 is an example of the electric field measured as the EFSG 125 dove to 85 m. The bottom panel is of the observed electric field for a DC electric dipole source of strength about 430 A•m. The top panel is the spectrogram for the E-field measurements, which exhibits the broadband effect of the system noise spikes. For the most part the noise events are of short duration. A longer period of noise, caused by the Seaglider motor moving its battery pack used for trim adjustments, occurred as shown in the bottom panel. The middle panel is the observed EF on Ch. 2 showing low noise between brief operations of glider systems. The proof is that the E-field system has a noise figure that permits observation of the Schumann resonances caused by global lightning at 7.8, 14, 21, … Hz.

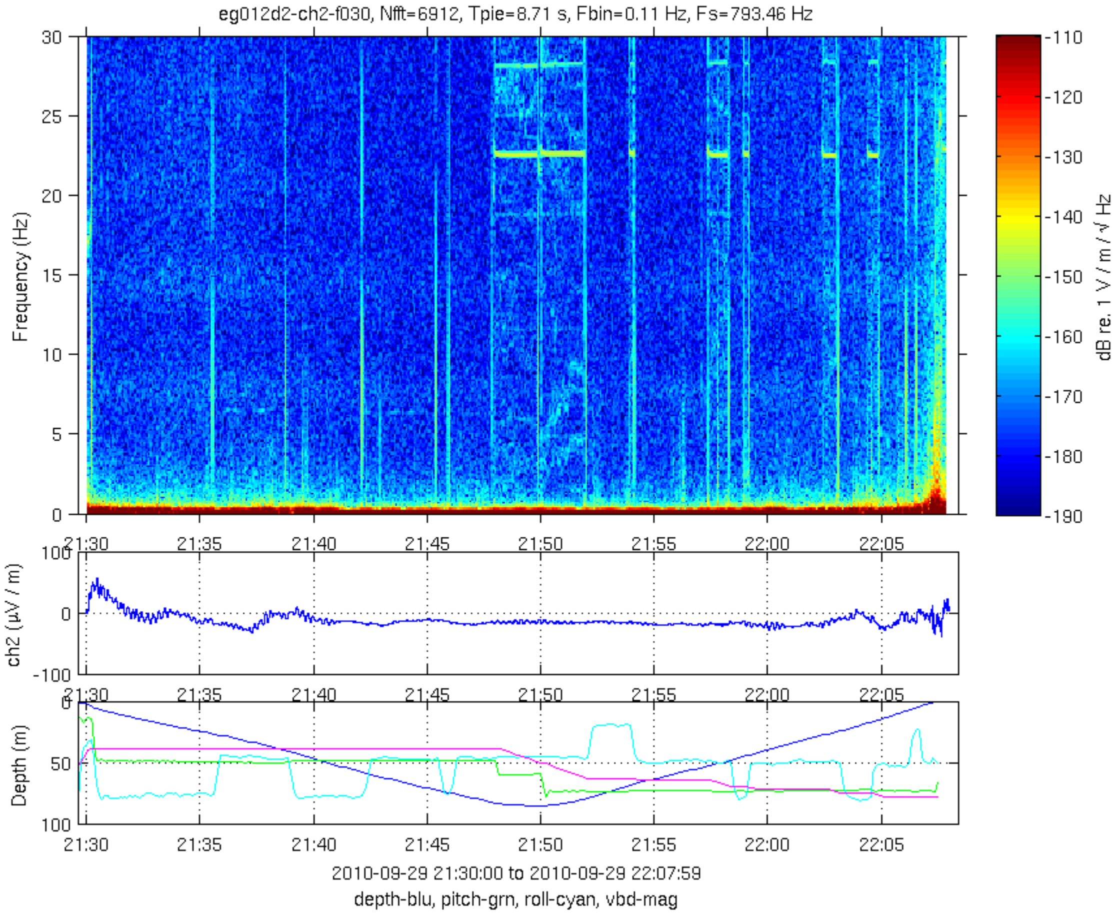

Fig. 4: (Top) Spectrogram for single-axis EFSG analysis of Pre-ASWEET. Schumann resonances are evident at 7.8, 14 and 21 Hz, indicating very good E-field performance. Various systems produced broadband noise in the E-field record. (Middle) Time series of EF on mission 12, dive 2. (Bottom) Depth profile (blue), pitch (green), roll (cyan) and VBD bleed (magenta). VBD is Variable Buoyancy Device – a pump that fills an external bladder to decrease glider density.

IMPACT/APPLICATION

The E-field sensor provides an additional capability for diverse, multi-sensor detection schemes. The more limited detection range will, in some cases, be an advantage. First, the sensor is not sensitive to distant sources. Thus, detection implies localization. Second, it is more of a point vector sensor that can provide information about source heading, CPA and speed.

RELATED PROJECTS

*Ocean Electric Field Studies for Oceanography (*N00014-08-1-1278). This is the SecNav/CNO Chair in Oceanographic Sciences. This grant supports two graduate students, Kevin Taylor and Nathan Lauffenburger, in UW School of Oceanography. Kevin is engaged in the studies of EM-APEX floats in ONR's QPE DRI. Nate is engaged in ONR's Lateral Mixing DRI. The PI conducts broad-based studies of ocean electrodynamics on this grant.

PUBLICATIONS

Sanford, T. B., J. F. Price and J. B. Girton (2010). Upper ocean response to Hurricane Frances (2004) observed by profiling EM-APEX floats, *J. Phys. Oceanogr.*, in press.

HONORS/AWARDS/PRIZES

Awarded The Henry M. Stommel Research Award from the American Meteorological Society, January 2010

Elected Fellow of the American Meteorological Society, January 2010